PRELIMINARY DRAFT
FOR DISCUSSION ONLY

POSSIBLE ALTERNATIVE SOLUTIONS TO THE PROBLEM OF MERCURY CONTAMINATION OF BERRYS CREEK TIDAL MARSH

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in '72, when thought 6" contam., sugg. scraping then reestab. marsh but now know 36" contam.

I. No Action

The marsh will be left as it presently is. No attempt will be made to remove or treat the mercury contamination of the marsh.

A. Advantages

1. Open space is preserved. The marsh will continue to provide nesting sites for waterfowl and refuge for waterfowl and mammals.

2. If Berrys Creek presently is contaminated with mercury then Berrys Creek Tidal Marsh probably is removing mercury from Berrys Creek.

3. No cost.

B. Disadvantages

1. The marsh probably is acting as a source of mercury for wildlife in the estuary.

2. Conversion of inorganic mercury to more toxic organomercurials may be taking place in the marsh.

3. Even if the marsh is removing mercury from Berrys Creek at present, changes in Berrys Creek (such as the elimination of mercury discharges to Berrys Creek or increases in dissolved oxygen or salinity concentration) could cause the marsh to act as a mercury source for Berrys Creek.

II. Dredging to Remove All Mercury Contaminated Sediment (Feick et al., 1972).

A temporary dike would be built to prevent contaminated sediment from reaching Berrys Creek. The marsh would be vacuum dredged and the dredge spoils placed in a landfill lined with an impermeable material. A new marsh would be created in the area which was dredged.

An area of approximately 130 acres must be dredged to a depth of at least 3 feet. This means at least 630,000 cubic yards of sediment must be dredged. The cost involved in dredging this much sediment is at least $2,205,000. Reestablishment of a salt marsh would require at least 630,000 cubic yards of sandfill. The sandfill would cost between $1,890,000 and $2,047,500.

A. Advantages

1. The mercury contaminated sediments are placed in containment.

2. A more productive marsh than the one which presently exists can be established.

B. DISADVANTAGES

1. A suitable site must be found for the disposal of at least 630,000 cubic yards of contaminated dredge spoil.

2. Leachates from the containment may be polluted.

III. DREDGING TO REMOVE ALL MERCURY CONTAMINATED SEDIMENT AND RECOVERY OF THE MERCURY (HARLIN, 1972).

This alternative is the same as alternative II except that the mercury would be recovered from the dredge spoils by roasting or chemical leaching. The spoils then could be placed in a landfill or returned to the marsh area.

The cost of dredging the sediment would be at least $2,205,000. The cost for 630,000 cubic yards of sandfill would be $1,890,000 to $2,047,500.

A. ADVANTAGES

1. There would be no danger of mercury eventually leaching from the landfill area.

2. The mercury is recovered and recycled. At least temporarily, it is removed from the marsh ecosystem.

3. Cost of the actual recovery of the mercury may be self-liquidating. Assuming an average of 30 mg/kg mercury in the first 3 feet of sediment there are approximately 5100 pounds of mercury that are potentially recoverable. At the 1974 retail price of 30 dollars per pound the mercury is worth $153,000.

4. Returning the decontaminated dredge spoil to the marsh would decrease the amount of fill material needed in order to reestablish the marsh.

5. A more productive marsh than the one which presently exists can be established.

B. DISADVANTAGES

1. The leaching method is least effective on sediments with high organic contents.

2. Contaminated sediments would be transported to proper facilities, and the decontaminated sediments would be transported to a landfill or returned to the marsh. The cost of trucking will be between $1 and $2 per cubic yard in each direction. The total cost of trucking will be between $1,260,000 and $2,520,000.

IV. Leaching of Mercury in Place by Hypochlorite Solution (Harlin, 1972).

A temporary dike would be constructed to isolate the marsh from Berrys Creek. The marsh would be surrounded by an impermeable material to form an impoundment. Water would be drained from the marsh and sediments within the impoundment would be treated with hypochlorite solution. Hypochlorite leachate containing solubilized mercury would be collected. Mercury would be recovered from the leachate by reducing with an active metal, by sulfide precipitation, or by carbon adsorption. Marsh vegetation would be reestablished on the leached sediments.

It was estimated by Harlin (1972) that leaching would cost between $5,000 and $10,000 per acre. For the entire marsh the cost would be $650,000 to $1,300,000, plus the costs for diking, labor, and other unidentified tasks.

A. Advantages

1. The mercury is permanently removed from the ecosystem.

2. The mercury is recovered and recycled.

3. No soil is removed and no fill is required except for the dike.

B. Disadvantages

1. Hypochlorite leaching is expected to be least effective on soils with high organic content. It is not possible to estimate the effectiveness of the method at this time.

2. The effect of the hypochlorite leach on soils with respect to reestablishment of the marsh is not known.

V. Iron-Sand Overlay Method (Harlin, 1972).

A dike would be constructed and the water would be drained from the marsh. Six inches of iron in the form of crushed auto bodies would be placed on the marsh and covered with 6 inches of sand. The iron-sand overlay would present an impenetrable barrier to mercury migration from the sediment. A freshwater marsh or a terrestrial environment could be established on top of the sand. The cost of the iron-sand overlay method was estimated by Harlin (1972) to be $2,500 to $3,000 per acre. The cost for the entire marsh would be $325,000 to $390,000, plus the costs for diking and other unidentified tasks.

A. ADVANTAGES

1. Mercury is immobilized beneath the iron-sand overlay. This isolates the mercury from the ecosystem.

2. Iron reduces methylmercuric ion to less toxic elemental mercury.

3. Open space can be preserved as a freshwater marsh or a terrestrial environment.

4. The area could be incorporated into site development plans for use in the future. Purchase of riparian rights would benefit State educational funds.

B. DISADVANTAGES

1. The iron in contact with the sediment could increase mercury mobility. The likelihood of this occurring is small.

2. Highly toxic dimethylmercury could be formed by the reaction of the methylmercuric cation with iron. The probability of this reaction occurring is small because the reaction involves a methyl transfer and the concentration of methylmercuric cation is expected to be low.

3. The present marsh is under 6 inches to 1 foot of water at high tide. Reestablishment of a salt marsh would require that the 1 foot of iron-sand overlay be covered with 6 inches of topsoil or sand. Thus, in order that the reestablished marsh be under 6 inches to 1 foot of water at high tide, dredging of 18 inches of existing sediment would be required. All the advantages, disadvantages, and costs of dredging, disposal of the dredge spoil, and/or mercury recovery would be incorporated in this alternative.

4. The effectiveness of an iron-sand overlay has not been demonstrated under field conditions.

VI. POLYMER FILM OVERLAY (WIDMAN, 1972).

A dike would be built, the marsh would be drained, and vegetation would be removed. A polymer film would be spread over the marsh to prevent mercury migration. A freshwater marsh or a terrestrial environment could be established over the polymer film. Reestablishment of a salt marsh would require dredging prior to placement of the polymer film.

The cost for sufficient nylon 6 polymer (polycaprolactam) to cover the marsh would be approximately $120,000.

A. ADVANTAGES

1. Mercury is immobilized beneath the polymer film.

2. Open space can be preserved as a freshwater marsh, a terrestrial environment, or a saltwater marsh.

B. DISADVANTAGES

1. Dredging would be needed if a saltwater marsh is to be reestablished.

2. The effectiveness of the polymer overlay under field conditions is uncertain.

3. The life-expectancy of the polymer overlay under field conditions is uncertain.

VII. WASTE WOOL OVERLAY (TRATNYCK, 1972).

This alternative is the same as alternative VI except that waste wool is used as the overlay material. Waste wool acts as a barrier to mercury migration by the sorption of mercury.

Raw material costs would be $2,900 to $5,800 per acre. The cost of raw materials to cover the entire marsh would be $377,000 to $754,000.

A. ADVANTAGES

1. The advantages are the same as for method VI.

B. DISADVANTAGES

1. Dredging would be required if a salt marsh is to be reestablished.

2. The effectiveness of waste wool as an overlay material has received only preliminary laboratory evaluation and has received no field evaluation. The life expectancy of the waste wool overlay under field conditions is not known.

VIII. CHEMICAL FIXING AGENTS (FEICK, 1972).

A dike would be constructed, the marsh would be drained, and vegetation would be cleared. Mercury would be fixed in the sediment by spreading a neat long chain alkyl thiol, an inorganic sulfide, or proteinaceous material on the sediment. A 1/2 inch thick covering of sand would be needed to prevent oxidation of the fixing agent. A freshwater marsh or terrestrial environment could be established over the sediment containing the fixed mercury.

Assuming an average of 30 mg/kg mercury dry weight in the sediment the cost of n-dodecyl thiol needed would be approximately $950. Ferrous sulfide would cost approximately $1,200 and natural proteinaceous material in the form of chicken feathers would cost $11,000. The 1/2 inch thick sand cover would cost approximately $26,000 to $28,500.

A. ADVANTAGES

1. Mercury would be immobilized by the fixing agent.

2. Open space in the form of a saltwater or freshwater marsh or a terrestrial environment could be preserved.

B. DISADVANTAGES

1. Odor problems could be severe if an alkyl thiol fixing agent is used. Thiols are characterized by their strong, unpleasant odors. An odor problem also may occur if a natural proteinaceous material is used.

2. The use of a sulfide fixing agent could lead to formation of highly toxic dimethylmercuric sulfide.

3. The chemical fixing agent may provide little or no immobilization above that presently provided by the sediment.

4. The effect which the fixing agent would have on the establishment of a freshwater marsh or terrestrial environment or on the reestablishment of a salt marsh is not known.

5. Natural proteinaceous material would be biodegradable and could release mercury to the environment eventually.

6. The effectiveness of chemical fixing agents has not been established under field conditions.

IX. USE OF A GETTERING SYSTEM (SUGGS ET AL., 1972).

A temporary dike would be built, the marsh would be drained, and vegetation would be removed. A sulfur coated, cotton mesh getter would be placed on the surface of the sediment. The dike would be removed and the marsh would be inundated. When sufficient mercury had been removed another temporary dike would be built and the getter removed. A salt marsh would be reestablished. Mercury would be recovered from the getter by roasting or the getter would be buried in an appropriate landfill.

A. ADVANTAGES

1. A salt marsh would be reestablished.

2. Mercury is recoverable from the getter.

B. DISADVANTAGES

1. Gettering is slow and inefficient. In a 2 inch thick layer of sediment contaminated with 200 ppm mercury, 2% of the mercury will be gettered in 3 months. Rates of mercury removal probably will be lower at lower mercury concentration.

2. It is not known from how deep beneath the surface of the sediment mercury would be removed.

3. Gettering will be least effective for sediments high in organic ~~mercury~~ content.

4. The method has not been tested under field conditions.

X. SAND AND GRAVEL OVERLAY (BONGERS, 1972).

A temporary dike would be constructed. If a terrestrial environment or a freshwater marsh is to be created, the vegetation would be removed. A sand or gravel layer at least 6 cm thick would be spread over the sediment to form an impenetrable barrier. The terrestrial system or freshwater marsh would be created on top of the sand or gravel. If a tidal marsh is to be reestablished, approximately five feet of sand or gravel fill would be placed on the marsh to compress the sediment. After a minimum of several weeks most of the sand or gravel would be removed. The remaining sand or gravel would be at least 6 cm thick to provide a barrier to mercury migration. The tidal marsh would be reestablished over the sand or gravel layer. Alternatively, dredging could preceed placement of sand fill if a tidal marsh is to be reestablished.

Sufficient sand fill to cover 130 acres to a depth of five feet would cost approximately $3,150,000 to $3,412,500. The cost of sand fill to cover 130 acres to a 6 cm (2.4 inches) depth is between $126,000 and $136,500.

A. ADVANTAGES

1. Mercury is immobilized beneath the sand.

2. Open space could be preserved in the form of a terrestrial system or a freshwater or a saltwater marsh.

3. Sand fill for compression is readily and immediately available. Sand fill being used for the construction of highways and the Sports Complex could be stored on the marsh until used. This would substantially reduce the cost of the sand used for compression of the marsh.

B. DISADVANTAGES

1. If the need for a dredge and fill permit from the United States Army Corps of Engineers delays implementation till a ready supply of sand fill is no longer available, the cost of compression of the marsh by sand fill would rise substantially. The cost of the sand fill would be $3,150,000 to $3,412,500.

2. The immobilization of mercury beneath sand has not been field tested.

XI. IMPOUNDMENT OF BERRYS CREEK TIDAL MARSH

A permanent dike would be built to isolate the marsh from Berrys Creek. A freshwater marsh or a terrestrial system would be established.

A. ADVANTAGES

1. Mercury is isolated from the estuarine ecosystem.

2. Open space is preserved.

B. DISADVANTAGES

1. Wildlife would continue to ingest and accumulate mercury.

2. If a freshwater marsh is established, inorganic mercury may be converted to the more toxic organic form by the marsh sediment.

3. The contribution of a potentially productive tidal marsh to the estuary would be lost.

XII. PAVING OF THE MARSH

A permanent dike would be constructed to isolate the marsh from Berrys Creek and the marsh would be drained. Fill material would be placed over the sediment. The fill would be covered with paving material.

A. ADVANTAGES

1. Mercury would be isolated from the estuarine system.

2. Payment for riparian lands would add funds to State educational programs.

B. DISADVANTAGES

1. The contribution of a potentially productive tidal marsh to the estuary would be lost.

2. Future use would not be traditional open space. The area could become part of Sportsplex parking fields or could be used for future activity.

None are field tested, all lab tests.

LITERATURE CITED

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Tratnyck, J. P. 1972. Waste wool as a scavenger for mercury pollution in waters. Washington, U. S. Environmental Protection Agency, 49 pp.

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General Site Background

Between 1929 and 1974, various chemical companies operated a mercury processing plant which was situated on approximately 7 acres in the northwest corner of the 40 acre tract referred to as the Wood-Ridge property. For the majority of the 45 year operating period, untreated mercury-containing waste effluent was discharged into Berry's Creek.

Little is directly known about the mercury processing operations at the site prior to 1960; subsequently, the plant primarily manufactured:

- Mercury Oxides
- Inorganic Mercury Salts
- Phenyl Mercuric Acetate Powders
- Other Phenyl Mercuric Powders
- Phenyl Mercuric Solutions
- Triple Distilled Mercury

For a 3 year period, zirconium-based materials my have been produced or warehoused at the facility by a tenant, Magnesium Elecktron, Inc. (formerly Melberk, Inc.; derived from Magnesium Elecktron and F.W. Berk).

About half of the mercury consumed by the facility was converted to oxides, primarily for the Mallory Battery Company. The mercury sources were; ores (e.g., cinnabar), customer-owned mercury and plant mercury. In addition the facility produced some fungicides, bactericides and specialty chemicals.

Attachment XXV provides product lists from the former processing facilities.

Other materials that are known to have been used at the site include:

- Acetic acid
- Benzene
- Boric Acid
- Carbon disulfide
- Chlorine
- Cinnabar
- Dimethyl amine
- Ferric sulfate
- Lime
- Nitric acid
- Sodium hydroxide
- Zirconium hydroxide

The facility maintained a distilling operation to purify and recover mercury from both in-plant waste and customer waste (e.g., amalgams, batteries, thermomerters, etc.). It is presumed that essentially the same type of materials were handled, the same chemical processes employed, and similar products were manufactured prior to 1960.

Some of the remaining property, particularly the 19 acres between the plant and Berry's Creek, was utilized until 1968 for disposal of wastes that include those from the recovery operation. The area was also operated for at least 5 years as a landfill for municipal-type wastes from sources that included the Borough of Wood-Ridge. For an unknown period of time that commenced in 1962, a nearby plant which manufactured sulfonated naphthalene formaldehyde condesates was granted permission to dispose of a calcium sulfate sludge on the site.

In 1975, the Wood-Ridge plant ceased operation and the 7 acre parcel was sold to Wolf Realty Company which demolished the processing plant, excavated the top soil, and isolated the subsurface soils beneath two warehouses and a parking lot which were constructed on the site. Velsicol Chemical Corporation retains ownership of the undeveloped 33 acre tract.

An historical chronology of events at the site is presented in the report prepared for the Department by Jack McCormick and Associates, Inc. entitled, "Investigations of Aquatic and Terrestrial Mercury Contamination in the Vicinity of the Former Location of the Wood-Ridge Chemical Corporation Processing Plant, Boroughs of Wood-Ridge and Carlstadt, Bergen County, New Jersey".

Enforcement Background

Extensive efforts by Federal and State regulatory offices to have the potential responsible parties take voluntary corrective action repeatedly failed and resulted in NJDEP initiating suit against Ventron (Morton Thiokol), Velsicol, et. al. in 1976 for their role in the long term mercury contamination of the Berry's Creek ecosystem. The trial court ruled the companies were liable for the cost of the cleanup and removal. The chemical companies appealed this lower court decision to the Appellate Court and in 1981, the lower court decision was upheld. The companies made their final appeal to the New Jersey Supreme Court and on January 10, 1983, the Supreme Court heard arguments by the defendants and the State. On July 21, 1983, the Supreme Court decided all points of the appeal in favor of the State.

It is noted that as part of the decision rendered by the trial Court, NJDEP was required to prepare a "Cleanup Plan for Berry's Creek" for the courts consideration. NJDEP prepared a plan without the benefits of the necessary remedial investigation and feasibility study work. The Cleanup Plan provided for the dredging of a 12,000 foot stretch of Berry's Creek to a depth of 4 feet (approximately 175,000 cu. yds) with placement of the sediments in a secure dewatering/disposal facility to be constructed on 19 acres of the Wood-Ridge property. Additionally, a cutoff slurry wall was proposed around the perimeter of the disposal site.

This plan was conditionally accepted by the trial court pending receipt of all necessary permits to implement the cleanup. The major permit required was a COE 404 Dredging Permit. NJDEP made application for the 404 permit in September 1981. The COE review of the application resulted in their determination that an Environmental Impact Statement would be necessary to properly evaluate the impact of the proposed dredging plan and, in turn, decide whether to issue the 404 permit. The COE issued a "Suggested Berry's Creek EIS Data Collection and Analysis Program" in January 1983 to NJDEP delineating the

data based required of the applicant (i.e., the State NJDEP) in order for the COE to prepare the EIS. This COE document is provided as Attachment XIX.

In January 1984, Velsicol Chemical Corporation and Morton Thiokol, Inc. initiated negotiations with the state for the purpose of developing a mutually acceptable Consent Agreement to conduct a comprehensive RI/FS at the site incorporating the data collection required for the COE Environmental Impact Statement as well as the provisions of an RI/FS conducted under the Federal Superfund program. The initial failure of the negotiations in reaching a signed Consent Agreement resulted in NJDEP filing an application with the USEPA for Superfund monies. On September 23, 1984 USEPA awarded the grant monies to NJDEP to conduct the RI/FS. The negotiations with the two (2) companies, which had proceeded in earnest during USEPA's consideration of NJDEP's grant application, ultimately proved to be successful and NJDEP declined the Superfund monies. On October 26, 1984, NJDEP, the 2 corporations, and the Superior Court executed a document entitled "Stipulation and Supplementary Order Approving Cooperative Agreement for Remedial Investigation and Feasibility Study and Amending Procedural Order Involving Remedy" which is essentially a Consent Agreement and is often referred to as the "Stipulation". This Stipulation outlines the terms, conditions, and responsibilities of the State and the corporations in completing the RI/FS (See Attachment XXIV).

Response Actions To Date

State regulatory agency involvement with the site began in the late 1950's when the New Jersey Department of Health, a predecessor to the NJDEP, performed inspections and sampling at the plant. From the time of the first inspection and through the 1960's the NJDOH unsuccessfully sought either the elimination of the total industrial discharge into Berry's Creek or an acceptable level of pretreatment prior to discharge.

Beginning in approximately 1970, numerous field inspections and sampling efforts were conducted by and/or on behalf of NJDEP, USEPA, Hackensack Meadowlands Development Commission, New Jersey Sports and Exposition Authority, and the processing plant property owners. The sampling included soils, ground water, surface water, sediments, and to a more limited extent, air and biota. The sampling was for various purposes including, but not limited to, research, general environmental monitoring, public health assessments and litigation. These investigations have documented that the physical environment within the study area boundaries is heavily contaminated with mercury and other contaminants as more fully described in the ERM Report entitled "Task 1 Literature Search and Preliminary Background Investigation Report which is appended as Attachment XX.

Other past actions taken have been the award of research contracts by NJDEP's Office of Science and Research to various academic institutions for specific phenomena such as sediment transport, mercury uptake in fish, and mercury methylation.

Presently, there is an ongoing water quality monitoring program of Berry's Creek being carried out by the HMDC and more fully described in Attachment XXI. In addition, NJDEP has awarded a contract to the U.S. Army Corps of Engineers Waterways Experiment Station to comprehensively address the questions of metal transformations and bioaccumulation of Berry's Creek sediments under

various Eh, pH, and salinity conditions as well as mercury volatilization in Berry's Creek. This latter scope of work is more fully described in Attachment XXII.

Nature and Extent of the Problem

Although records are very sketchy or nonexistent for much of the operating history of the mercury processing plant, it is known that the effluent discharge form the plant directly into Berry's Creek continued untreated for approximately 40 years and that industrial plant waste was landfilled onsite. Estimates of the amount of mercury contamination in the Berry's Creek ecosystem range from 50 tons to 400 tons.

The numerous site investigations conducted since the early 1970's have documented that the physical environment in the vicinity of the Wood-Ridge property is heavily contaminated with mercury and contaminated with other heavy metals to a lesser extent. Excessive levels of mercury can be found in water, soils, and sediments on and adjacent to the property. It has further been determined that a zone of heavy mercury contamination extends southward in Berry's Creek and in the tidal marshes adjacent to Berry's Creek with mercury levels consistently and significantly higher upstream from Patterson Plank Road. The data to date further indicates that mercury contamination of fish is evident with mercury body burdens of fish near the Wood-Ridge site higher than the body burdens of fish captured upstream of the site or downstream of Patterson Plank Road. Of the 92 killifish samples that have been analyzed for mercury to date (see ERM Report), 16 of 64 whole body tissue analyses and 13 of 28 individual organ tissue analyses displayed a mercury concentration above 1.0 ppm. A more limited sampling of the air has also indicated mercury levels above background. The lack of data concerning the presence of organic compounds precludes a meaningful assessment of the distribution of such compounds. It is noted that the laboratory analysis of the Berry's Creek sediment shipped to the USACOE WES in early 1986 displayed PCB levels at up to 100 ppm. A complete description of the results of the laboratory analysis of the "research" sediments is provided in Attachment XXIII.

This widespread mercury contamination as well as the other chemical contaminants documented to exist within the environmentally sensitive Hackensack Meadowlands pose major environmental concerns. While mercury can remain stable and immobile under certain conditions, it can become mobilized and when released into the environment can result in bioaccumulation by aquatic and terrestrial organisms. From a human health standpoint, the potential for ingestion of contaminated biota by man is of considerable concern. Another potential route of exposure to man is via mercury volatilization especially during the warmer months.

Project Complexity

Most sites for which the Department has requested Remedial Investigation/Feasibility Study proposals usually address either a former facility, a landfill, wetland or an impoundment/waterbody. As noted earlier in Section 2.0, the site under consideration includes at least one of each of these potential release sources/receptors. To further complicate the situation, there are (1) two other Superfund sites (i.e., Scientific Chemical Processing - Carlstadt and Universal Oil Products - East Rutherford) that

potentially impact Berry's Creek, (2) a major ECRA (Environmental Cleanup and Responsibility Act) site (former Diamond Shamrock facility) that potentially impacts the Creek, and (3) numerous other point source and non-point source discharges that impact the creek and marsh. The Department will coordinate these various investigations to insure that the data gathering efforts of each is not unnecessarily duplicated and will make available to the Berry's Creek contractor the results.

A significant level of investigative effort has been directed at the Berry's Creek study areas. ERM-Southeast, Inc. was engaged to review, compile and summarize the extensive existing data that primarily relate to the concentrations of mercury and other heavy metals in environmental receptors (refer to Attachment XX - Volume I of the ERM study). However, an accurate definition of the horizontal and vertical extent of mercury in the Berry's Creek sediments on the basis of past data is precluded by the constant transportation of sediments up and down the creek by tidal action. Infrequent flood tide storm events may result in punctuated shifting of creek sediments along the breadth, as well as the length, of the creek.

In addition to the above-noted factors, the bioavailability of mercury is a function of the methylated mercury concentration available for uptake by the biota and the methylation rate which is primarily determined by bacterial action. Microbial processes can convert inorganic mercurial compounds into organic forms that may bioaccumulate in fish and biomagnify in food chains. Accordingly, two intensive laboratory studies are being performed by the Corps of Engineers Waterways Experiment Station to ascertain the bioavailability of mercury in Berry's Creek sediments to aquatic organisms and to quantify the influence of environmental variables on mercury methylation and migration in Berry's Creek.

With respect to the land-based site, groundwater movement is complicated by the tidal influences and much of the area is heavily overgrown with Phragmites during the summer and fall seasons.

Data obtained from all of these studies will be utilized by the successful bidder to determine the need for remedial measures in an around Berry's Creek that address the mercury problem, while considering the presence of other contaminants. The role of the marshes, as sources or sinks or mercury, must be addressed.

The Department's goal is to select the best qualified cost-effective consulting firm to conduct this complex study. The fact that remedial actions directed at the creek could include dredging, covering and bypassing the contaminated channel, bidders will be expected to demonstrate the ability to evaluate environmental and cost relationships on the basis of wetland and estuary experience. Cost estimates, merely on the basis of standard construction handbooks, will not be acceptable.

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FIGURE 4-1 SMALL SCALE MASTER MAP REFERENCE LOCATIONS TO SAMPLE SITES

4-2

SCALE: 1" = 2000'